

**An Inventory of Climate Change Projects in select United States
Affiliated Pacific Islands (Guam, Commonwealth of the Northern
Mariana Islands, Republic of Palau, the Federated States of
Micronesia, and the Republic of the Marshall Islands) – A
preliminary overview of past and present climate change work.**

Prepared by

Romina King, PhD
Assistant Professor of Geography
University of Guam
HSS, 2nd Floor, Rm 220C
UOG Station,
Mangilao, Guam 96923
T. 671.735.2880
Email. roking@triton.uog.edu

Prepared for

David Helweg, PhD
Director of the Pacific Islands Climate Science Center

Date of report: 01 July 2016
Time Period: 01 April 2015 – 01 April 2016

Funded under USGS Cooperative Agreement G15AC00122

Table of Contents

LIST OF FIGURES	3
LIST OF ACRONYMS	4
EXECUTIVE SUMMARY	0
INTRODUCTION	2
STUDY AREA	2
PICSC STRATEGIC SCIENCE AGENDA	3
AIM AND OBJECTIVES	3
ORGANIZATION AND APPROACH	5
CHALLENGES	6
RESULTS/ANALYSIS	6
CLIMATE-CHANGE PROJECTS MATRIX	6
INFORMAL INTERVIEWS	7
STAKEHOLDER MEETING	8
WHAT ARE SOME OF THE BARRIERS TO ADAPTATION?	9
WHAT DO GUAM AND MICRONESIA NEED TO ADAPT TO THE IMPACTS OF CLIMATE CHANGE?	12
CONCLUSION AND RECOMMENDATIONS	15
REMOTE SENSING	15
LEVERAGING	15
RESILIENCY OF SMALL BUSINESSES	16
KNOWLEDGE MANAGEMENT	16
RESEARCH	16
REFERENCES	17
APPENDIX A – RESULTS OF A GUAM/CNMI STAKEHOLDER MEETING HELD ON 13 APRIL 2015 AT THE HYATT REGENCY HOTEL, TUMON, GU.	18
APPENDIX B – LIST OF ATTENDEES AT THE GUAM/CNMI STAKEHOLDER MEETING HELD ON 13 APRIL 2015 AT THE HYATT REGENCY HOTEL, TUMON, GU.	22

List of Figures

Figure 1: Map of the Pacific Basin Area. Reprinted from USDA NRCS (1999). Shows the national and state boundaries of Guam, CNMI, the Republic of Palau, the FSM, the RMI, and American Samoa. Also shows some of the uninhabited USAPI, and the main Hawaiian Islands.	4
-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	---

List of Tables

Table 1: No. of climate change projects that address a theme from the PICSC Science Agenda. Some projects may address more than one theme.....	7
------------------------------------------------------------------------------------------------------------------------------------------------	---

List of Acronyms

CNMI	Commonwealth of the Northern Mariana Islands
COFA	Compact of Free Association
CSC	Climate Science Center
DOD	Department of Defense
DOI	Department of the Interior
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
FSM	Federated States of Micronesia
IPCC	Intergovernmental Panel on Climate Change
LCC	Landscape Conservation Cooperatives
LiDAR	Light Detection and Ranging
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NCCWSC	National Climate Change and Wildlife Science Center
PDO	Pacific Decadal Oscillation
PICCC	Pacific Islands Climate Change Cooperative
PICSC	Pacific Islands Climate Science Center
POC	Point of Contact
RMI	Republic of the Marshall Islands
SAC	Stakeholder Advisory Committee
TNC	The Nature Conservancy
UAV	Unmanned aerial vehicle
UOG	University of Guam
USAPI	United States Affiliated Pacific Islands
USFW	United States Fish and Wildlife Service
USGS	United States Geological Survey
WB	World Bank

EXECUTIVE SUMMARY

This report identifies needs and opportunities in the United States Asian Pacific Islands (USAPI) region relative to climate change science, management, and adaptation strategies. The region includes the territories of Guam and American Samoa, the Commonwealth of the Northern Marianas (CNMI), and the independent states of Palau, Federated States of Micronesia (FSM), and the Republic of the Marshall Islands (RMI). This inventory is responsive to the Pacific Islands Climate Science Center (PICSC) Strategic Science Agenda and its articulation with the region. A matrix was created organizing past and present climate change projects occurring in the USAPI. Projects were evaluated as to whether they addressed any of the four themes outlined in the PICSC Strategic Science Agenda (see Helweg et al., 2014).

Based on this matrix, there are approximately 19 various U.S. Federal agencies and 8 international institutions that have programs that oversee climate science projects in the Pacific. In total, there are approximately 148 past and present climate change projects occurring in the USAPI within Micronesia. This is a conservative estimate because several programs have not officially listed their projects on their Web sites. There may be more that are not accounted for in this matrix.

With regard to the 148 past and present climate change projects in relation to the themes from the PICSC Science Agenda, 67 projects addressed *Guidance for Anticipated Intermediate-Term Climate Changes*; 21 projects addressed *Potential Effects of Changing Climate on Freshwater Resources*; 23 projects addressed *Anticipating and Addressing Change in Coastal and Low-lying Areas*; and 34 were related to *Forecasting Sustainability for Resource Management and Planning*. Some of these projects addressed more than one theme, hence, the total number of is greater than 148.

In addition to the matrix, informal interviews with official Points of Contact (POC) for Climate Change were conducted and a preconference stakeholder meeting was held to obtain information about jurisdiction needs.

The following recommendations have emerged to serve the region through PICSC and include the following:

- capacity building in remote sensing and geo-spatial products that assist the small islands in Micronesia to adequately prepare for impacts of climate change,
- economic valuations of ecosystem functions, small-business resiliency plans, and cost-benefit analyses of adaptation,
- a regional repository of climate change research, organized and updated by a competent care-taker,
- additional focused research on freshwater resources, and

- translation services or communicating climate science to a variety of stakeholders in a meaningful manner.

INTRODUCTION

The ecosystems, people, and cultures of the Pacific Islands are expected to be affected by climate change and natural climate variability (Nurse et al., 2014). Impacts of anthropogenic climate change include increases in average air and sea surface temperatures and sea level rise (Intergovernmental Panel on Climate Change, 2013). In an effort to proactively deal with the effects on rivers, aquifers, forests, coral reefs, as well as the flora, fauna, and human communities that depend on such systems Secretary of the Interior Ken Salazar signed Secretarial Order 3289 (14 September 2009, amended 22 February 2010), “Addressing the Impacts of Climate Change on America’s Water, Land, and Other Natural and Cultural Resources.” S.O. 3289 established the creation of Climate Science Centers (CSCs) and Landscape Conservation Cooperatives (LCCs). LCCs are managed by US Fish and Wildlife. There are eight CSCs managed by the United States Geological Survey (USGS) National Climate Change and Wildlife Science Center (NCCWSC). In the Pacific, the CSC and LCC work closely together.

The Pacific Islands Climate Science Center (PICSC) was established in 2011 and is one of eight regional Climate Science Centers (CSCs). The CSCs are overseen by the United States Geological Survey (USGS) National Climate Change and Wildlife Science Center. The purpose of the CSCs is to provide region-specific scientific information, tools, and techniques to assist natural resource managers anticipate, monitor, and adapt to climate change.

The PICSC is a consortium of universities in the central and western Pacific Ocean region (University of Hawaii-Manoa, University of Hawaii-Hilo, and the University of Guam). In addition to these academic institutions, PICSC collaborates heavily with local and federal government agencies, non-governmental organizations, community organizers, and cultural leaders. The PICSC consortium and partners provide expertise in developing and applying climate change science to societal and ecological challenges across the region. The PICSC is led by a director who is advised by USGS and a Stakeholder Advisory Committee (SAC). The PICSC can fund projects through the following mechanisms:

1. Release of a national Request for Proposals
2. Direct solicitation of research proposals or work plans by the PICSC Director
3. Solicitation of research proposals by the university host directors.

The mechanisms use review processes to ensure the quality of proposals, including relevance to PICSC science priorities, and cost-effectiveness.

Study Area

The PICSC services the U.S. affiliated Pacific Islands (USAPI). The USAPI includes Guam, the Commonwealth of the Northern Mariana Islands (CNMI), American Samoa, the

Federated States of Micronesia (FSM)¹, the Republic of Palau, the Republic of the Marshall Islands (RMI), the Hawaiian Islands, and several uninhabited atolls² (see Figure 1). This report is primarily concerned with USAPI jurisdictions within Micronesia and focuses on Guam, CNMI, FSM, the Republic of Palau, and the RMI. There is less emphasis on the RMI due to guidance from the PICSC Director (Helweg 2016, personal communication). RMI would be the responsibility of the main PICSC office, in addition to American Samoa and the Hawaiian Islands.

PICSC Strategic Science Agenda

The direction of the PICSC and allocation of funds is largely driven by its five-year Strategic Science Agenda, 2014-2018, (see Helweg et al., 2014). The agenda emphasizes ‘actionable science’—science designed to be integrated into strategic planning (Helweg et al., 2014). Ideally, products of actionable science should inform policy and management about the sustainability of human and ecological communities, in order to increase resiliency to climate change.

Four major science themes in the PICSC Science Agenda were identified as priority areas for the USAPI:

- Theme 1: Guidance for Anticipated Intermediate-Term Climate Changes
- Theme 2: Potential Effects of Changing Climate on Freshwater Resources"
- Theme 3: Anticipating and Addressing Change in Coastal and Low-Lying Areas
- Theme 4: Forecasting Sustainability for Resource Management and Planning

Each of these themes has approximately two or three objectives (see Helweg et al., 2014).

Aim and objectives

The aim of this report is to provide guidance in identifying opportunities to implement the PICSC Strategic Science Plan for future years within the USAPI, particularly Guam, CNMI, FSM, and the Republic of Palau.

¹ The FSM includes Yap, Chuuk, Pohnpei, and Kosrae

² Uninhabited atolls include Baker Island, Howland Island, Jarvis Island, Johnston Atoll, Kingman Reef, Midway Atoll, Navassa Island, Palmyra Atoll, Wake Island

ORGANIZATION AND APPROACH

In order to identify opportunities to implement the PICSC strategic science plan, this review of current and past climate change projects in the USAPI was conducted. A research assistant, Nelmar Cruz, was hired under the USGS-PICSC Cooperative Agreement with UOG, to help organize information.

A matrix was designed to include information for the following fields

- Federal Agency or International Institution/Government
- Federal Agency Office/Department
- Federal Programs within Agencies
- Person in Charge (contact)
- Program Objective
- Projects
- Project Objective
- Cost of Project (funding)
- Project PI
- Institution
- Project Location
- Partners
- Start date
- Date completed/Projected completion date

Projects were evaluated as to whether they address any, some, or all of the following PICSC Science Agenda themes:

- Theme 1: Guidance for Anticipated Intermediate-Term Climate Changes"
- Theme 2: Potential Effects of Changing Climate on Freshwater Resources"
- Theme 3: Anticipating and Addressing Change in Coastal and Low-Lying Areas
- Theme 4: Forecasting Sustainability for Resource Management and Planning

An 'x' was marked in any of the themes the project addressed. Some projects addressed more than one theme and was adequately recorded.

The location of the projects was also considered and noted. The following locational fields were included in the matrix:

- None
- Guam
- CNMI
- FSM
- RMI
- Palau
- American Samoa

In addition to this matrix, informal conversations were held with points of contacts (POCs) for climate change from Guam, the CNMI, the Republic of Palau, and the FSM³. Discussions centered around island specific-needs.

A formal pre-conference strategic meeting was convened on 13 April 2015 at the Hyatt Regency Hotel, Tumon Guam (see Appendix B for a list of participants).

Challenges

In order to compile this matrix, staff were trained in Zotero, a reference management website and given a crash course in climate change regional governance. Intermittent funding delayed the timely start of the project and occasionally disrupted continuity for staffing and reporting.

RESULTS/ANALYSIS

Climate-change projects matrix

There are 13 federal natural resource agencies (including PICSC) with funded climate change programs (Halofsky et al., 2015). In addition to these 13 federal natural resource agencies, there are additional federal agencies and several international governmental and non-governmental agencies conducting climate change work in Micronesia. For PICSC to be most effective, it is important to catalog and assess how these past and current climate change projects are related to the four themes of the PICSC science agenda. With the assistance of PICSC funded graduate research assistant, a climate change projects matrix was constructed.

Based on this matrix, there are approximately 19 various U.S. federal agencies and 8 international institutions that have programs that oversee climate science projects in the Pacific. In total, there are approximately 148 past and present climate change projects occurring in the USAPI within Micronesia. This is a conservative estimate because several programs have not officially listed their projects on their Web sites...there may be more that are not accounted for in this matrix. For example, the National Science Foundation has funded several grants under various themes (e.g., National Ecological Observatory Network and Dynamics of Coupled Natural and Human Systems) that may directly or indirectly address climate change. Another example includes the National Aeronautics and Space Administration (NASA). NASA produces several remotely-sensed datasets from various Earth missions that greatly contribute to current climate science. An email was sent to these programs (e.g., NASA and NSF)

³ POCs include Tricee Limtiaco (Guam), Fran Castro (CNMI), Xavier Matsutaro (Republic of Palau), and Cindy Ehmes (FSM).

requesting information for a list of their respective projects that they fund. Most programs did not have an official list. For agencies that did reply, their responses were included in the current matrix.

The U.S. State Department has several programs supporting climate change related projects. Unfortunately, their full resources could not be inventoried due to funding and staffing exigencies discussed above. U.S. State Department supports embassies and consulates throughout the region and funds climate change projects through various mechanisms such as U.S. Aid. All U.S. Aid work in the region has been catalogued.

With regard to the 148 past and present climate change projects, 67 projects addressed *Guidance for Anticipated Intermediate-Term Climate Changes*; 21 projects addressed *Potential Effects of Changing Climate on Freshwater Resources*; 23 projects addressed *Anticipating and Addressing Change in Coastal and Low-lying Areas*; and 34 were related to *Forecasting Sustainability for Resource Management and Planning* (Table 1). Some of these projects addressed more than one theme, hence, the total number of projects from Table 1, is greater than 148.

Table 1: No. of climate change projects that address a theme from the PICSC Science Agenda. Some projects may address more than one theme.

Themes from the PICSC Science Agenda	No. Projects that address this theme
Guidance for Anticipated Intermediate-Term Climate Changes	67
Potential Effects of Changing Climate on Freshwater Resources	21
Anticipating and Addressing Change in Coastal and Low-Lying Areas	23
Forecasting Sustainability for Resource Management and Planning	34

Informal Interviews

Informal interviews were conducted in 2015 and part of 2016 with climate change POCs about how the PICSC can assist with science needs of their respective jurisdiction and the relationship to the PICSC agenda. All interviewees noted that the science agenda

seemed to be heavily focused on Hawaii and would like to see more representation of Micronesia in future projects.

In addition to the POCs, several local⁴ and federal⁵ natural resource managers were consulted. Most emphasized a need for GIS technical expertise and data analysis, in order to increase island resiliency to climate change. John Lawrence, NRCS PIA Assistant Director of Field Operations, succinctly summarized many of the thoughts regarding GIS,

“Detailed GIS mapping for typical southern Guam or Palau landscapes, delineation of micro drainages, is needed for degraded land restoration. This detail will logically guide planning for degraded grassland restoration and management. GIS detailed mapping will identify critical sediment transport pathways to define sites for prioritized treatment and define cultural resource sites and access corridors for restoration crews, and recreation. In combination with existing veg [sic] cover and soils geodata, local resource managers will have a graphical tool to help predict wild fire behavior as well as guide fire pre-suppression planning or post fire treatment. This same geodata can be used to site and design rain gardens to provide more pervious open green-space. This same geodata maybe used to map urban storm-water pathways thus ensuring groundwater recharge instead of channeling rainwater into storm drains that have the most direct negative impact on wetland and coral reef health.”
(Lawrence 2015, personal communication)

Many local natural resource managers voiced a desire for a dedicated GIS training venue that offered regular training sessions and offered immediate troubleshooting and strategic guidance, similar to the old NOAA Pacific Services Center, only much more localized and sensitive to each local agency’s needs.

Stakeholder meeting

To help identify Guam’s needs with respect to adaptation to climate change in an inclusive, collaborative process, an open PICSC-Guam group was organized. The first planning strategic meeting was held on 13 April 2015 at the Hyatt Regency Hotel. During this meeting, presentations were given by Dr. Mark Lander (UOG) concerning the current typhoon regime and Dr. Kirsten Oleson (UH-Manoa) regarding the economics of climate change. Also in attendance were representatives from the CNMI. After these presentations, two questions were posed to the group:

⁴ Local resource managers informally interviewed include Edwin Reyes (Guam Coastal Management Program), Walter Leon Guerrero (Guam Environmental Protection Agency), Evangeline Lujan (Guam Water Authority), Christine Camacho-Fejeren (Guam Department of Agriculture, Forestry Division), Marvin Aguilar (Department of Land Management), Anna Simeon (Bureau of Statistics and Plans), Whitney Hoot (Bureau of Statistics and Plans), Pilar Carbuillido (Guam Department of Homeland Security),

⁵ Federal resource managers include Val Brown (NOAA Fisheries), Adrienne Loerzel (NOAA CRM), Michael Mann (US EPA Region 9), John Lawrence (USDA NRCS),

- What are some of the barriers to adaptation?
- What do Guam and Micronesia need to adapt to the impacts of climate change?

Attendees were invited to post their responses on sticky notes. Sticky notes were grouped according to topic and discussed. The official responses are provided in Appendix A. The following sections provide a succinct summary of the responses to both questions and how the general emerging themes compare with the themes outlined in the PICSC Science Agenda.

What are some of the barriers to adaptation?

Based on the responses, seven major themes emerged:

1. Knowledge gaps
2. Communication
3. Political
4. Economic
5. Social/Cultural
6. Natural

Each of these themes will be individually addressed.

Knowledge gaps

There have been several comments noting the lack of accessibility to knowledge, research, and content knowledge experts. An online repository, or annotated living bibliography, curated by a trusted climate change clearinghouse focused on Micronesia was suggested by several people. The repository should contain the best available peer-reviewed scientific journal articles, as well as copies of relevant grey literature (e.g., publically-funded vulnerability assessments). It should also include datasets and data models (e.g., dynamically downscaled climate models of specific countries). While logistics were not fleshed out, one idea briefly entertained was that such a repository could be housed at the University of Guam within the Center for Island Sustainability, servicing Guam and Micronesia. Prior to this occurring, cyberinfrastructure at UOG needs to be updated and connectivity to other islands, particularly to the community colleges needs to be improved. It is also imperative that this repository is managed by a reliable individual who will manage and update references and datasets in a timely manner.

Other knowledge gaps include the lack of information that examines the opportunities of climate change in Guam and the region. Professors interested in agriculture noted that climate change might adversely affect current crop growth, but may be conducive to other, more lucrative crops. In that same line of reasoning, there is little to no

research examining economic costs and opportunities of climate change for Guam and the rest of Micronesia.

In terms of content knowledge experts, it was noted that there were several island-states that did not have a state climatologist and very few have a dedicated office within the government that has a climate change office. Other knowledge barriers include the lack of investment in key research areas such as the paleoclimate, typhoons, El Niño/La Niña cycles (ENSO), the Pacific Decadal Oscillation (PDO), freshwater availability in atolls. One final barrier mentioned refers to modeling. Currently there is one downscaled model for Guam and the Pacific and there has not been wide-spread acceptance on its outputs.

Communication

Barriers to adaptation to climate change under the 'communication theme' are the lack of awareness, lack of a cohesive, consistent message in a culturally sensitive manner. Several participants (mostly academics) also lamented on a lack of scientific literacy among students and government officials. Scientific literacy may be defined as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (U.S. National Research Council, 1996). This definition has been further expanded to include the ability of a person to "ask, find, or determine answers to questions derived from every day experiences", or rather, "describe, explain, and predict natural phenomena" (*Next Generation Science Standards*, 2013). The academics present believed there is a lack of understanding between natural climate variability and climate change and it has to do with a lack of science literacy.

While a scientifically literate society is desirable, beliefs about climate change risk were not positively correlated with scientific literacy, or numeracy (people's ability to comprehend and use quantitative information) (Kahan et al., 2012). Kahan et al. (2012) found that individual beliefs about climate change are largely determined by the values of the communities of the individual.

Political

In terms of regional political barriers to climate adaptation, the main 'barrier' raised pertains to migration to Guam from other areas of Micronesia. In terms of dealing with this migration, different political statuses within Micronesia and the various compacts of free association (COFA) that each of the sovereign states have with the United States were noted. Specifically, Guam is a territory of the U.S. and does not have control over its migration. Citizens of COFA island-states are allowed to move and work freely in the U.S. and its affiliated territories without visa restrictions.

Also, the nature of this COFA migration have not been recently investigated. Most COFA citizens have moved to Guam for educational and economic reasons (Levin 2015, 2008). It is unclear whether those reasons have changed and more relevantly how climate change is a direct or indirect cause for migration. A well-designed study with subsequent monitoring needs to be conducted.

There is a lack of local and regional planning to deal with migration due to sea level rise and coastal inundations. For instance, there is a lack of

- macro-planning focused on the issue of adaptation,
- political will at all levels to address climate (e.g., Calvo was the only Republican governor appointed to a national executive department climate change commission), and
- coordination of various sovereign island-states to formulate a strategy.

Economic

Economic barriers to climate change adaptation include lack of money, and, more notably, lack of human capital (i.e., qualified individuals who have a good work ethic and possess desired technical skill sets often willing to work for less than they are worth). This lack of capacity is much more of an issue than funding.

It is also important to be sensitive to land and marine tenure, which varies from island-state to island-state in Micronesia. This could be both a 'barrier' or an 'opportunity' depending on how the landowners perceive climate change and the importance of conservation.

Small and medium sized businesses on islands have often perceived that adaptation to climate change and sustainability are not complementary to business growth and development. The business community is particularly influential on Guam and it is crucial for them to be involved in climate adaptation. Businesses also tend to operate on shorter timelines of 20-30 year business cycles (i.e., not geological time scales) and may dismiss climate change as 'something for the next generation to worry about'. It is often perceived that investing in adaptation strategies to climate change may not yield immediate returns on investment.

Social/Cultural

Differences in culture or societal norms may also be barriers to climate change adaptation. Guam, unlike islands with homogenous populations, is culturally diverse. Not properly recognizing how different culture groups, and sub-culture groups (e.g., Yap mainland vs. Ulithi) deal with Guam's natural resource laws and accepted sustainable practices can be detrimental to the state of natural resources. It is crucial for Guam to address this.

One of the main barriers noted under ‘communication’ is the lack of a consistent message about climate change, especially considering the various culture groups on Guam. It is critical to provide clear, realistic, options on preparation and adaptation that are culturally interpretable and competent.

Natural

Natural barriers to climate change adaptation are local anthropogenic stressors that can hinder natural recovery. For example, arson delays watershed restoration efforts. A restored watershed would ideally reduce sedimentation to coral reefs downstream. A reduction of sedimentation is one less stress a coral reef has to face, especially within the context of increasing sea-surface temperatures which can trigger an increase in the frequency and severity of coral bleaching events.

What do Guam and Micronesia need to adapt to the impacts of climate change?

Based on the responses, the local needs of Guam and Micronesia may be categorized into seven major themes:

1. Knowledge gaps
2. Communication issues
3. Political support
4. Economic needs
5. Social needs

Some of these ‘needs’ are directly related to the ‘barriers’ mentioned in the previous section.

Knowledge

In order to address the research gaps noted under knowledge ‘barriers’, it was suggested that areas of investigation should include, but not be limited to the following topics:

One of the needs expressed by the majority of participants include a better understanding of actual climate history (baseline data from proxy sources). For example, short-term climate changes in the Pacific are driven by ENSO. Deepening the understanding of the relationship between regional drought and El Niño can provide knowledge to help direct island-specific freshwater management strategies.

Typhoons - a more comprehensive understanding of past and present typhoon behavior is needed because typhoons are linked to extreme rains, severe coastal erosion, and are usually major disasters for all islands. While it can be years between storms, the

physical, social, and economic devastation they can bring are concerns for all USAPI in Micronesia. There has been a typhoon vulnerability assessment done for Guam (see Guard et al., 1999), but it needs to be updated.

Other data needed were early indicators of climate change and what are/were the local natural responses to natural processes. Guam, in particular, is interested in the response of the aquifer to projected impacts of climate change. Research projects, funded by DOD and USGS, are exploring this topic, particularly through the Water and Environmental Resource Institute at the University of Guam. These could serve as an early warning system, provided that local natural resource agencies have to the capacity to support consistent monitoring of these resources.

An assessment of resiliency (both natural resources and for human communities), which could be included in the vulnerability study is currently being undertaken by the Government of Guam. From this assessment, ideally, there should be an exploration of proposed natural adaptation strategies that includes a feasibility study of the economic benefits and costs.

There was also a call for applied research in agriculture. Palau has done a study on salt-tolerant taro species (Matsutaro 2016, personal communication). Promoting locally grown agricultural products can decrease an island's dependency on imports, while stimulating the local economy. Investing in a study to assess which crops may fare better in a shifting climate, is one way to help direct policies on food security. This should include a market analysis and cost-benefit analysis.

There is a desire for a climate science clearing house that could also serve as a knowledge bank of available tools and models for small island developing states. More tools may not be necessary, but a thorough evaluation of existing tools that may be applied to the USAPI should be formally summarized and provided in a fact sheet, or pamphlet. Participants expressed a keen interest in the current downscaled model for the Pacific, created by the International Pacific Research Center (IPRC) at the University of Hawaii-Manoa. These model results debuted at the 2016 Center for Island Sustainability Conference, Guam. They were also presented at the 2016 FEMA Typhoon Resiliency Workshop, Guam. Issues still surround the uncertainty of the model. This needs to be conveyed in a clear, concise fact sheet. This effort is being led by Victoria Keener at the East-West Center. While this model was created specifically for Guam, participants questioned whether it may be applied to their respective islands.

While this downscaled model is the only one specifically available for Guam, it can provide two scenarios to explore questions that involve projected reef loss and biodiversity loss.

Participants felt that more detailed GIS data (e.g., digital elevation models), for all the islands and atolls, were needed for the region.

Communication/Education

With regard to climate science education, a two-prong approach was proposed. The first part would be to increase scientific literacy on Guam and the second part would be an investment in translation services. One need that was consistently repeated was the translation of existing information for wider audiences. A spokesperson, or a local champion, who has a background in communications and climate science and is sensitive to Micronesian cultures would be ideal in leading a strategy to translate existing climate science products, datasets, and state of knowledge. This person, with a background in communications should be trained in reaching various audiences using a variety of innovative techniques. One particular target audience that needs to be reached are local policy-makers, so that they can make informed decisions that support legislation for climate change adaptation. Additional translation services should include guidance for local agencies on what to do with these science products and how to 'mainstream' these products into their current mandates and workloads.

Political

A political need discussed was to increase collaborations between federal agencies, between local agencies, and between local and federal agencies. Everyone would like to see more meaningful and working relationships.

Social

Social needs to adequately prepare for climate change include an investigation of shifting demographics, particularly an updated study of COFA migration to Guam that explores whether people are moving to Guam due to impacts of climate change. This will inform federal policy on COFA migration and COFA-impact funding allocation to Guam and Hawaii. This will also inform the local government whether there is a need to formally prepare for 'climate refugees' in the form of a federally-funded program. Also, it is important to assimilate current and future COFA citizens with the formal laws and cultural norms of Guam that pertain to natural resource management.

Other social needs involve increasing local community support and commitments for addressing, mitigating, and ideally reducing local anthropogenic stressors to the environment, to allow the ecosystem to recover to the best of its ability. One popular example is arson. Most wildland fires are caused by arson, which severely hampers watershed restoration efforts. These wildland fires are much worse during drought years. Furthermore, there are many residents of Guam that are concerned with financial day-to-day survival (e.g., paying rent, paying for food) and are living from paycheck to paycheck. Environmental issues, climate change or even typhoon preparation may not be at the forefront of their priorities.

Economic

Economic ‘needs’ for climate adaptation include local, island-specific strategies to increase food and water security. This would include less dependency on exports and increasing the island’s ability to be self-sufficient. Many business-minded participants requested a cost-benefit analysis of present and future impacts of climate change, as well as an economic valuation of natural resources and ecosystem functions. It is also recommended higher coordination between local agencies in order to better leverage existing mechanisms to fund identified action plans towards adaptation.

CONCLUSION and RECOMMENDATIONS

There are several opportunities for implementation of the PICSC science agenda. These areas for collaboration are discussed below.

Remote sensing

Remote sensing technologies can advance the understanding of ecological questions relative to climate change especially when applied at different spatial and temporal scales, and using a variety of sensors. Remotely-sensed data are producing previously unattainable ecosystem structural and functional information. For example, full-waveform LiDAR and hyperspectral data products provide new capabilities to link, in novel ways, ecosystem structure and foliar chemistry with biogeochemical processes at scales from leaves to biomes. A variety of emerging remote sensing technologies are poised to dramatically increase understanding of ecosystem structure-function, helping to resolve long-standing fundamental questions within the biogeosciences.

The use of UAVs in developing low-cost geospatial datasets is also quite exciting and could provide a feasible solution for data-starved and lesser-developed island states.

Leveraging

There are at least 148 projects that address climate change in the USAPI. It is crucial to continue to build collaborations between federal agencies to leverage the limited budgets dedicated to the USAPI. It is also recommended to explore potential partnerships with the U.S. State Department. The sovereign USAPI are eligible to receive money from international institutions (e.g., Asian Development Bank, the German government) as well as from U.S. agencies such as U.S. AID targeting foreign polities. Working with projects funded from international sources would most likely require some coordination with the U.S. State Department or a non-governmental organization such as TNC.

Partnering with NASA through the UOG NASA-EPSCOR on some of their remotely sensed imagery would be beneficial, especially with Ocean Science programs such as PRISM.

Resiliency of small businesses

The Asian Development Bank and the World Bank have many projects focused on the economic aspect of adaptation to climate change. PICSC should further review some of these projects, especially with regard to sustainability. PICSC may want to include an economic cost-benefit component in some of their projects, which can further assist managers in seeing the value of particular management strategies.

Knowledge management

A central repository is recommended. Translation services or effective communication of climate change is in high demand, particularly from non-scientific natural resource managers and policy-makers.

Research

One particular topic that should be prioritized is ENSO and how it relates to the Pacific Decadal Oscillation (PDO). These natural cycles heavily control the near-term climate in the Pacific Ocean and occur during a human life span making it much easier for people to comprehend the timescale and thereby plan accordingly. Understanding how ENSO affects freshwater would be helpful to water management and directly impacts water security and food security.

REFERENCES

- Guard, C., Hamnett, M.P., Neumann, C.J., Lander, M.A., Siegrist, H.G., 1999. Typhoon Vulnerability Study for Guam (Technical Report No. 85). University of Guam Water Resources Center, Mangilao, GU.
- Halofsky, J.E., Peterson, D.L., Marcinkowski, K.W., 2015. Climate Change Adaptation in United States Federal Natural Resource Science and Management Agencies: A Synthesis. U.S. Department of Agriculture, Forest Service, Washington D.C.
- Helweg, D., Nash, S., Polhemus, D., 2014. The Pacific Islands Climate Science Center Five-Year Science Agenda, 2014-2018 (U.S. Geological Survey Open-File Report 2014-1075 No. 2014–1075). USGS.
- Intergovernmental Panel on Climate Change, 2013. Climate Change 2013: The Physical Science Basis. IPCC Working Group I Contribution to AR5.
- Kahan, D.M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L.L., Braman, D., Mandel, G., 2012. The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nat. Clim. Change* 2, 732–732, doi:10.1038/nclimate1547
- Levin, M.J., 2015. Migration in Micronesia Pacific Update 2014.
- Levin, M.J., 2008. The Status of Micronesian Migrants in the Early 21st century-A Second Study of the Impact of the Compacts of Free Association based on Censuses of Micronesian Migrants to Hawaii, Guam and the Commonwealth of the Northern Mariana Islands. Harvard University, Cambridge, MA.
- National Research Council (U.S.) (Ed.), 1996. National Science Education Standards: observe, interact, change, learn. National Academy Press, Washington, DC.
- Next Generation Science Standards: For States, By States, 2013. . National Academies Press, Washington, D.C.
- Nurse, L., McLean, R., Agard, J., Briguglio, L.P., Duvat, V., Pelesikoti, N., Tomkins, E., Web, A., Campbell, J., Chadee, D., Maharaj, S., Morin, V., van Oldenborgh, G.J., Payet, R., Scott, D., 2014. International Panel for Climate Change Working Group II: AR5 - Chapter 29: Small Islands. United Nations Environment Programme.

APPENDIX A – Results of a Guam/CNMI stakeholder meeting held on 13 April 2015 at the Hyatt Regency Hotel, Tumon, GU.

1. What are some of the barriers to adaptation? (Blue sticky notes)

Knowledge Gaps

- Content knowledge experts
- Beware downscaling. Natural variability overwhelms models uncertain.
- Need a repository for balanced scientific data summarized into accessible information.
- Data in region to relate to global models
- Too much research sits on shelves or in libraries
- Economic valuation of the resource to create info-based decision making
- Guam is not the same as Hawaii
- Need a state climatologist and a climate clearing house
- Reliable archiving and management of databases
- Might overlook or refuse to acknowledge important benefits (e.g., increase in crop production).
- Conditions could get better at times (e.g., no typhoons for 15 years).
- Overdependence on modeling approaches – going off in wrong direction
- Connection of health impacts attributable to adaptation and migration of populations
- An understanding of how climate change will directly affect the individual
- Time scale + natural variability confuse people, make it easier to put action off.
- It is going to take decades to perceive climate change

Communication

- Translation of existing information for wider audiences
- Many fingers in climate pie...inconsistent message
- Lack of message (no one is prioritizing it)
- Lack of consistent message
- Local champion to reach the local population regarding inputs
- Lack of sociocultural communications skill set
- Lack of 'climate' talk and linked to small holders
- Lack of awareness and understanding within those that are implementing
- Some industries trying to derail the work on climate change by denying it.
- Lack of solid understanding among local government about urgency to translate into concrete action - laws, policies, enforcement
- "now what" need translation services for agencies on what to do with the science.
- Lack of trust in the science and the people presenting impacts

Political

- There is a lack of planning to deal with migration due to sea level rise and coastal inundations.
- Lack of macro planning focused on the issue of adaptation
- Political will at all levels to address climate change
- Dysfunctional political system
- Politics (e.g., Calvo was the only Republican governor on an important group as stated this morning).
- Different political statuses come up with a regional approach

Economic

- Lack of money
- Lack of fiscal information
- Mitigate without being stupid, but we are stupid
- Topics aren't in strategic plans, which are tied to funding sources
- Values of land and ownership of land, especially coastal lands (e.g., The Chuuk Government owns no land, must lease it) Somewhat cultural
- Perception that adaptation is not complimentary to business development
- Long timelines lose immediacy of issue, keeps getting pushed back until might miss economic advantage of acting early.

Social/Cultural

- Need stronger cooperative extension service for islands (All Micronesian)
- Migration from people from low islands to high islands.
- Differentiate between low and high islands.
- No connection to private land owners (small holders)
- Lack of inclusion all of Guam's cultural diversity and some groups with low understanding of resource laws and sustainable practices not included in discussions or outreach.
- Give the population tangible options for how to prepare their home/community to adapt.

Natural

- Reduce local stressors

2. What do Guam and Micronesia need to adapt to the impacts of climate change?

Knowledge

- Drought linked to El Nino
- Typhoons are linked to everything else – extreme rains coastal erosion, disaster
- We have to clearly understand past-present and future typhoon behavior
- Downscale data
- Downscale data for everything
- Awareness of early indicators of climate change and present adaptation
- Link data and phenomenon.
- An assessment of resiliency (both natural resources and for human communities)
- Make resiliency relevant to private landowners.
- Need more vetiver grass
- Applied research on farm output land
- Agriculture research to understand what crops may fare better in shifting climate
- Reef loss/biodiversity loss
- Sea level rise
- Need better understanding of local natural responses to natural processes (e.g., how does the aquifer respond to sea-level changes)
- A solid understanding of specific impacts to each individual island
- Need better understanding of actual climate history (baseline data)
- Tools, models for small islands in Pacific (more tools/models exist for the Caribbean).
- Micronesia – more detailed GIS data
- Data QC is not trivial
- User beware – downscaling is not data
- Baseline data

Communication/Education

- Education is as important as research. 50% believe climate change not happening; 50% thinking it is.
- Barrier removal for community members
- Community awareness, perspective change
- Translated information on CC that increases awareness and understanding to illustrate these issues affect everyone and are everyone's responsibility (local buy-in)

Political

- Barrier for removal for legislative policy implementation
- Adaptation and absorption – the role of government to mobilize the agenda
- More effective FED + FED, LOCAL+LOCAL, FED + LOCAL and collaborative working relationships

Social

- Prepare for shifting populations – climate refugees
- Continue to pursue renewable energy development
- Policy on migration and compact-impact funding allocations
- Support/commitment for addressing/mitigating/reducing local stressors (silt nutrients, overharvesting) as a tool for building resilience to climate change
- Influx of settlers from atolls

Economic

- Better leverage existing mechanisms to fund needed actions
- Food security
- Water security
- Connect revenue money (GWA, GPA, TAF) to climate resilient communities
- Cost/benefits of the present and future impacts of climate change
- Less dependency on outside goods and services
- Active community pushing climate change projects
- Making the long-term impacts the interests/actions of the present

APPENDIX B – Matrix of Past and Current Climate Change Projects Occurring in the USAPI